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Future Climate Impacts of CBW BMP Efficiencies

A Modeling Sensitivity Study for Urban and Agricultural BMPs

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Project Overview

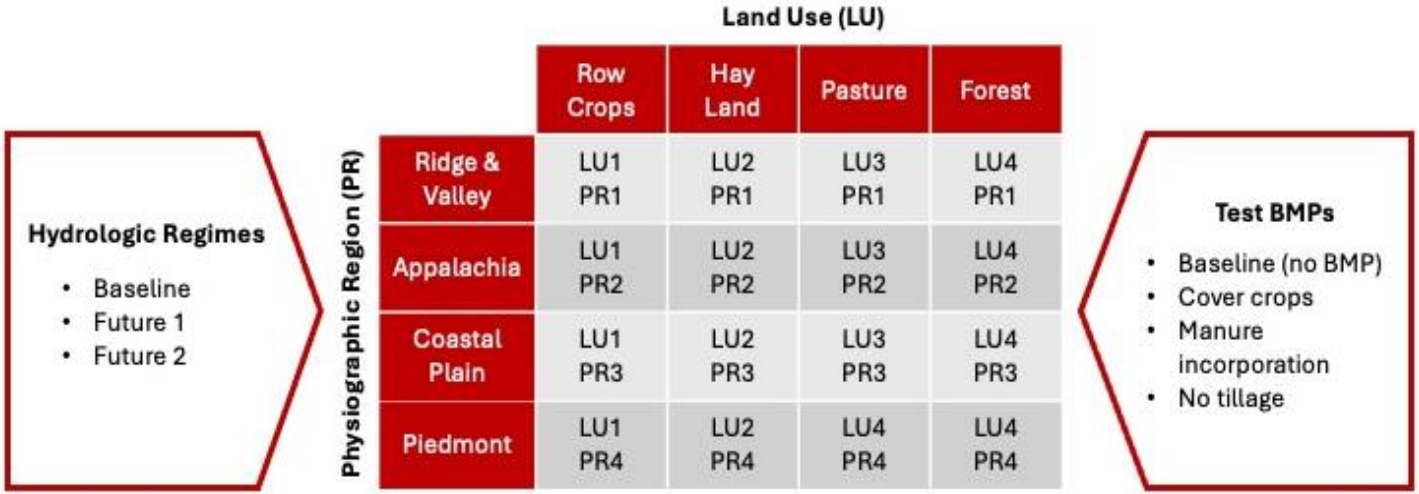
Goal: Quantify the performance of agricultural & urban BMPs in the Chesapeake Bay watershed under current and future climate scenarios

Tools: APEX for agricultural, SWMM for urban

Output: Pollutant removal efficiencies for different BMPs

Watershed Settings

- 4 regions
- 4 land uses
- 4 BMPs (row crops)
- hydrologic regimes in progress



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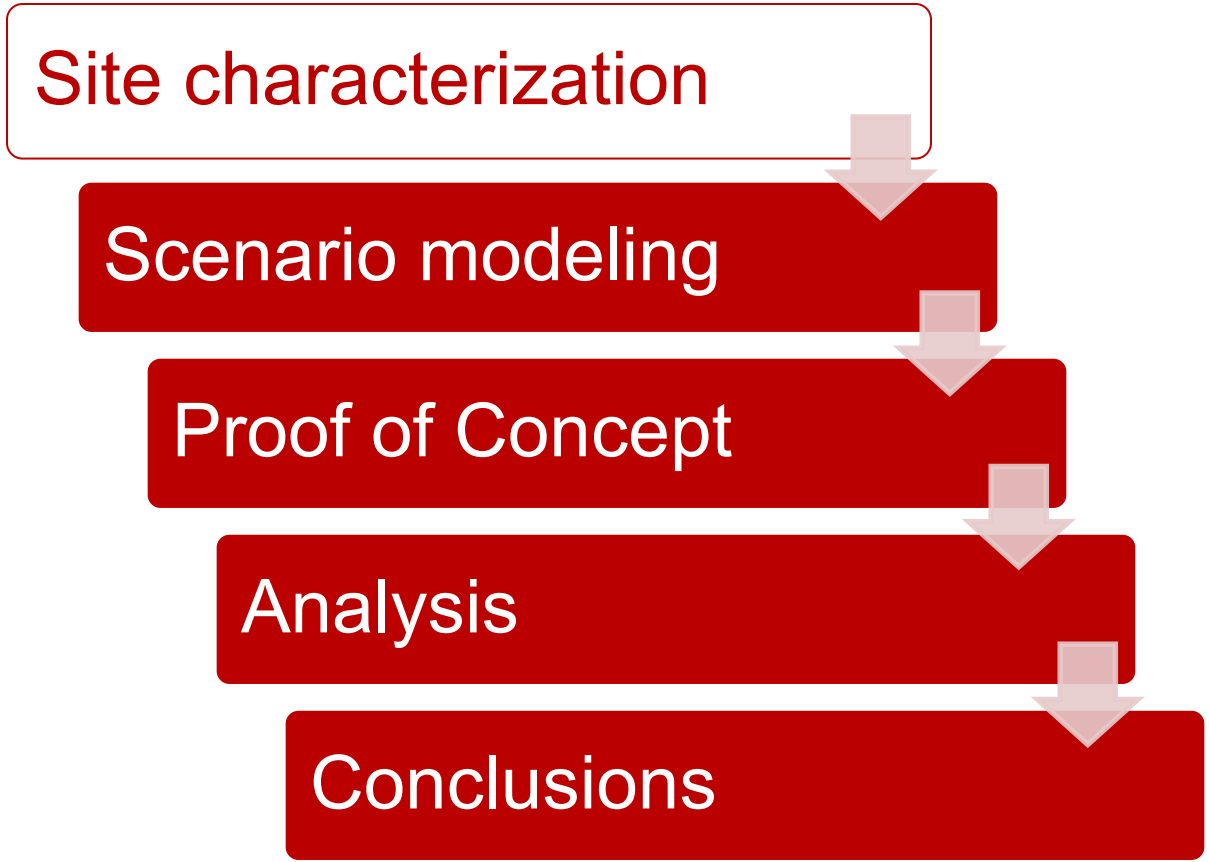
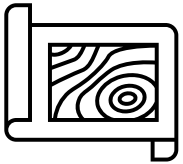

Site characterization
Scenario modeling
Proof of Concept
Analysis
Conclusions

Representative Sites

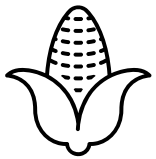


Physical Characteristics

- Averaged slope and soil textures across land segments within each region (via Gopal Bhatt & CBP team)
- Water table depth & groundwater variables (USGS data)

Climate Variables

- Baseline precipitation & weather data (1985-2000)



Agricultural Operations

- Crop selection based on CBP literature & USDA census
- Operation schedules from CAST model inputs (planting, harvest, fertilizer application)

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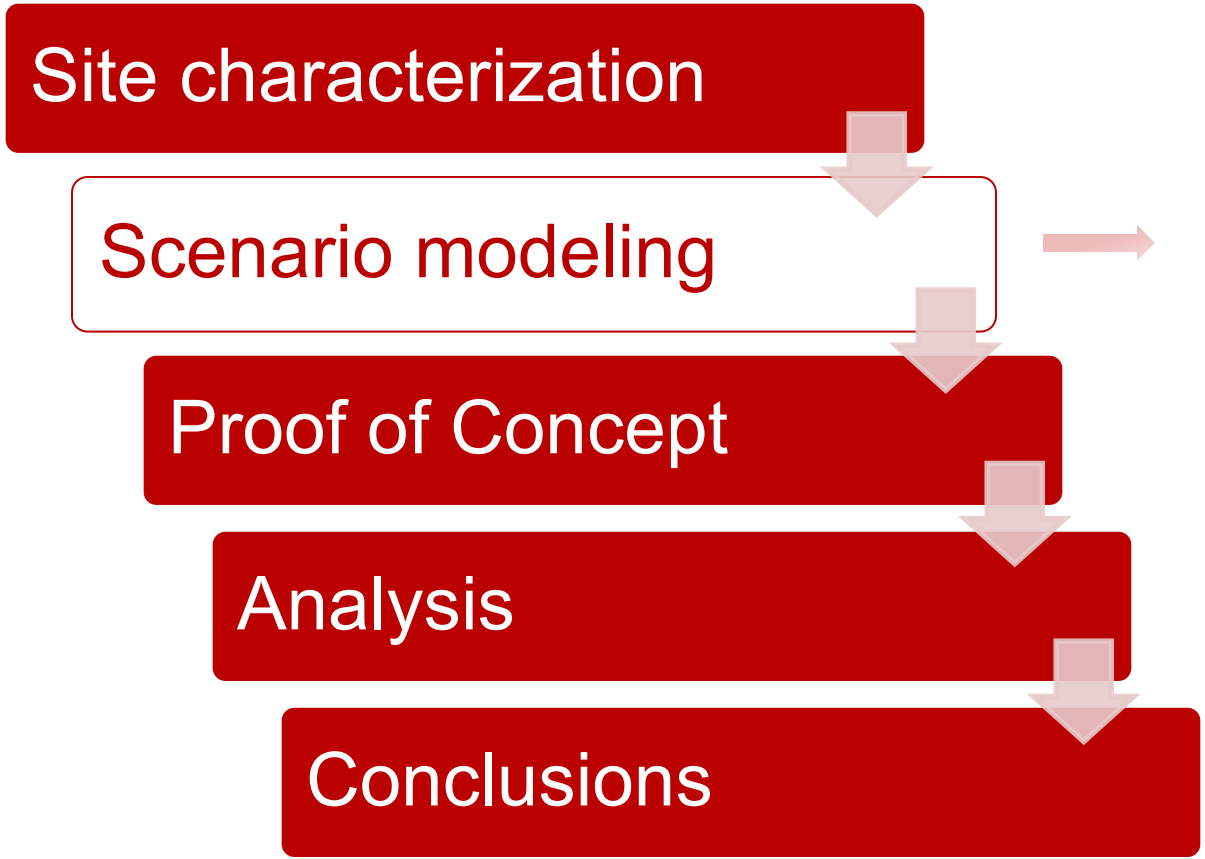

- ✓ Implemented baseline scenarios for each region + land use combo

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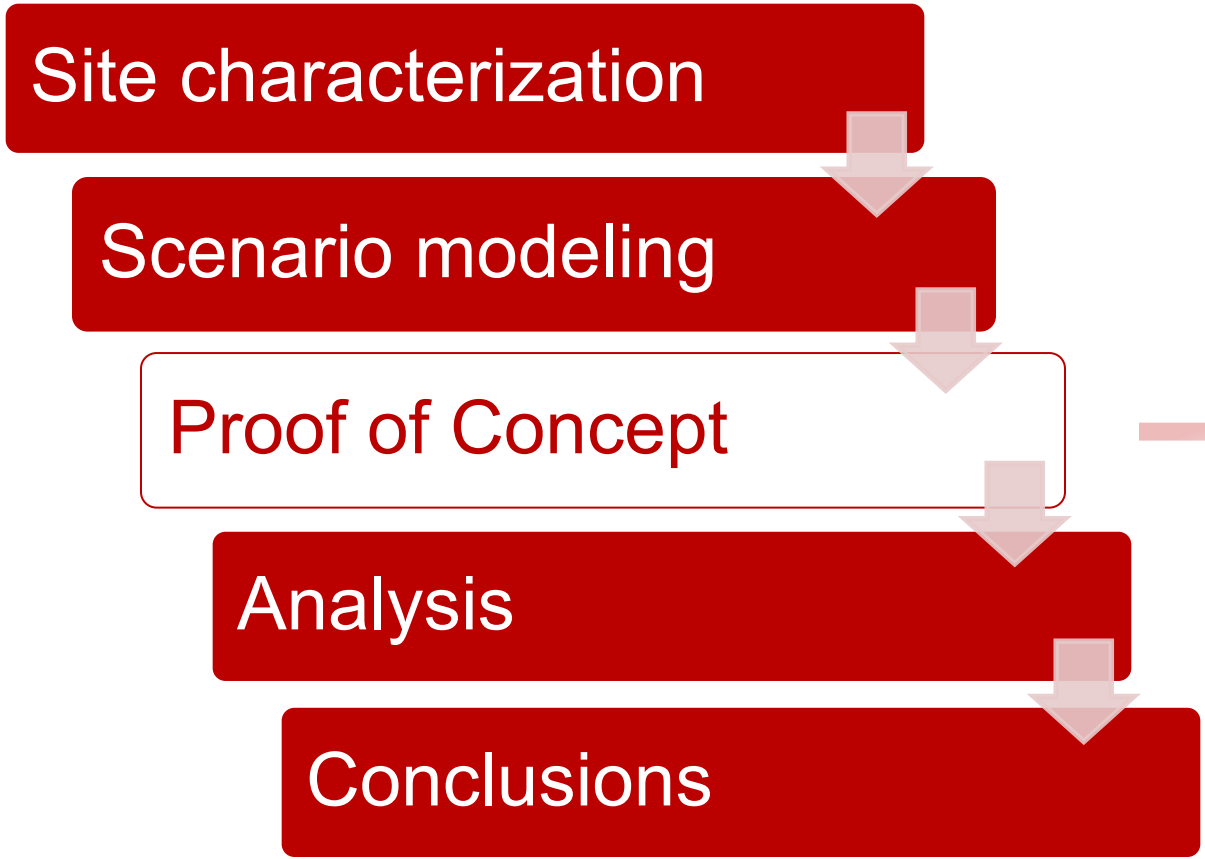
Baseline Files

Physiographic Region (PR)	Land Use (LU): Row Crops	Hay Land	Pasture	Forest
Ridge & Valley	LU1 PR1	LU2 PR1	LU3 PR1	LU4 PR1
Appalachia	LU1 PR2	LU2 PR2	LU3 PR2	LU4 PR2
Coastal Plain	LU1 PR3	LU2 PR3	LU3 PR3	LU4 PR3
Piedmont	LU1 PR4	LU2 PR4	LU4 PR4	LU4 PR4



- Validating baseline hydrologic components with CBP values

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Progress Delay: APEX Bug

```
IF(IHY>0)THEN
    NRF=0
    RFDT=0.
    YHY=0.
END IF
IF(INFL==4)THEN
    CALL HRFIN
RFV0(1)=RFDT(NRF)
    CALL WGN
    CALL WTAIR(1)
    X1=TMX(1)-TMN(1)
    TMX(1)=TMX(1)+TMXF(MO)
    TMN(1)=TMX(1)-TMNF(MO)*X1
    CALL WRLHUM(1)
    CALL WNSPD
    TMX=TMX(1)
    TMN=TMN(1)
    SRAD=SRAD(1)
    RHD=RHD(1)
    U10=U10(1)
ELSE
    I=NWTH
    IF(NGN>0)THEN
        DO
        I=1,NWTH
            II=I+KND

            !     READ DAILY WEATHER IF NOT
            GENERATED
            !  1  SRAD = SOLAR RADIAION(MJ/m2 OR LY)(BLANK TO
            GENERATE)
            !  2  TMX  = MAX TEMP(
            c)
            !  3  TMN  = MIN TEMP(
            c)
            !  4  RFV0 = RAINFALL(mm)(999. TO GENERATE OCCURRENCE &
            AMOUNT;
            !           -1. TO GENERATE AMOUNT GIVEN
```

- Logic error prevents reading of observed hourly precipitation *with* daily weather variables (Arnillas et al. 2025)
  - ➢ Hourly rainfall triggers random weather generation

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Progress Delay: APEX Bug

```
 IF(IHY>0)THEN
     NRF=0
     RFDT=0.
     YHY=0.
 END IF
   !!ED-ca1!!              IF(INFL==4)THEN    !!CA!! Reading/generating weather data.
   Estimation Methodology. `4` = Rainfall input at time interval DTHY.

   !!ED1-ca!!  This section replaces the previous if then statement to let the model
   information if available
IF(INFL==4) CALL HRFIN    !!CA!! !     THIS SUBPROGRAM READS RAINFALL AT TIME INTERVA
   !!ED1-ca!!
I=NWTH
IF(NGN>0)THEN
          DO I=1,NWTH
              II=I+KND
              !     READ DAILY WEATHER IF NOT GENERATED
              !  1  SRAD = SOLAR RADIAION(MJ/m2 OR LY)(BLANK TO GENERATE)
              !  2  TMX  = MAX TEMP(c)
              !  3  TMN  = MIN TEMP(c)
              !  4  RFV0 = RAINFALL(mm)(999. TO GENERATE OCCURRENCE & AMOUNT;
              !            -1. TO GENERATE AMOUNT GIVEN OCCURRENCE)
              !  5  RHD  = RELATIVE HUMIDITY(FRACTION)(BLANK TO GENERATE)
              !  6  U10  = WIND VELOCITY(m/s)(BLANK TO GENERATE)
              !  7  CO2I = ATMOSPHERIC CO2 CONC(ppm)
              !  8  REP  = PEAK RAINFALL RATE(mm/h)
              !  9  ORSD = OBSERVED SOIL SURFACE CROP RESIDUE(t/ha)
              READ(KRST(I),1070,IOSTAT=NFL)SRAD(I),TMX(I),TMN(I),RFV0(I),RHD&
              (I),U10(I),CO2I,REP,ORSD(I)
              IF(NFL/=0)THEN
                  NGN=-1
                  IRF=1
                  KGN=0
                  WRITE(KW(1),'(5X,A,A,3I4,1X,A80)')'GENERATED WEATHER STARTS',&
                  ' (Y M D)',IYR,MO,KDA,FWTH(I)
                  EXIT
```

- Logic error prevents reading of observed hourly precipitation *with* daily weather variables (Arnillas et al. 2025)
  - ➢ Hourly rainfall triggers random weather generation
- **Fix:** always check for daily variables regardless of hourly data
- Still validating

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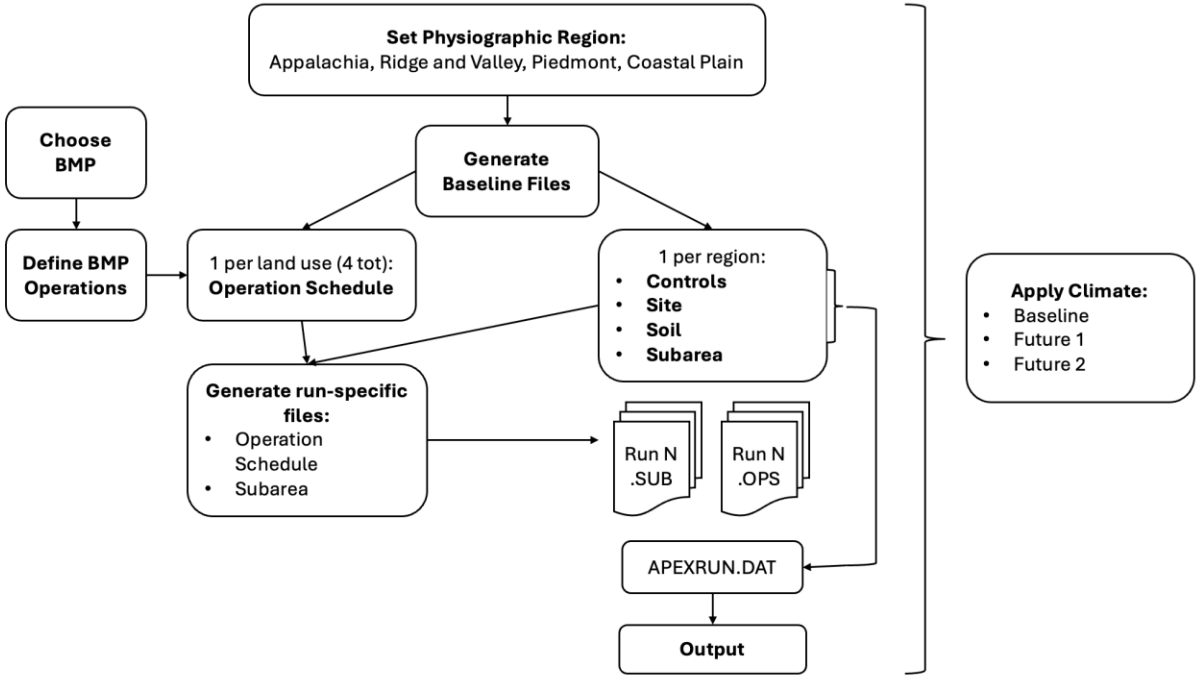
Workflow



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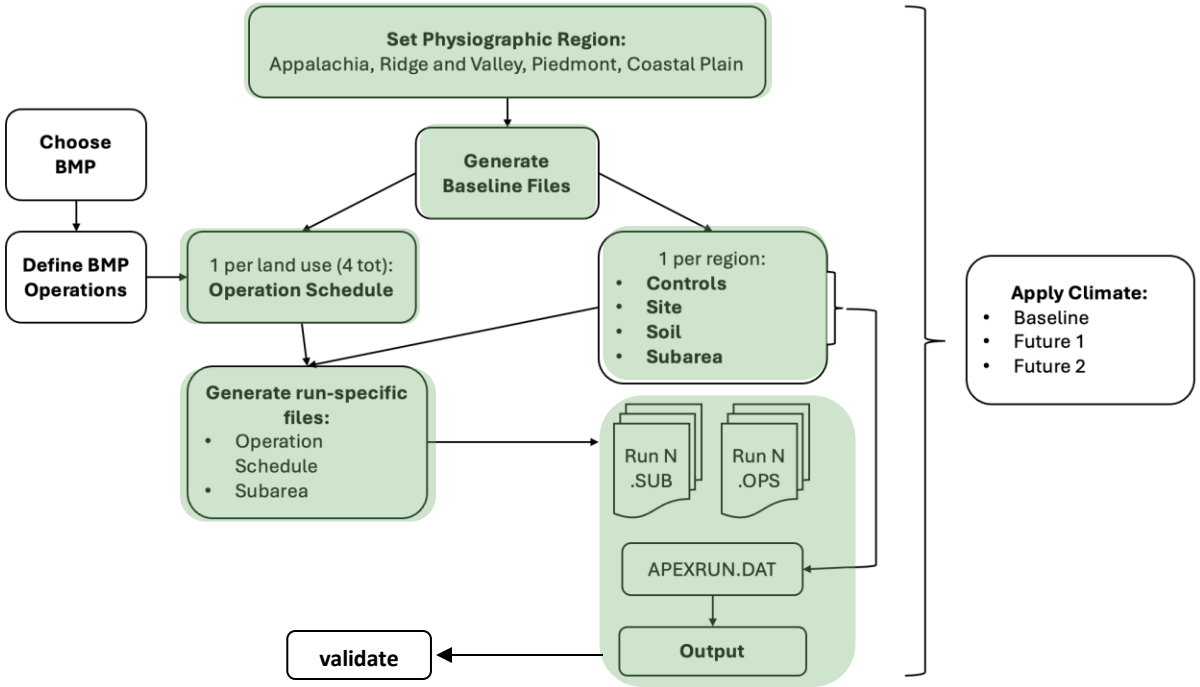
Workflow



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Scenario Validation

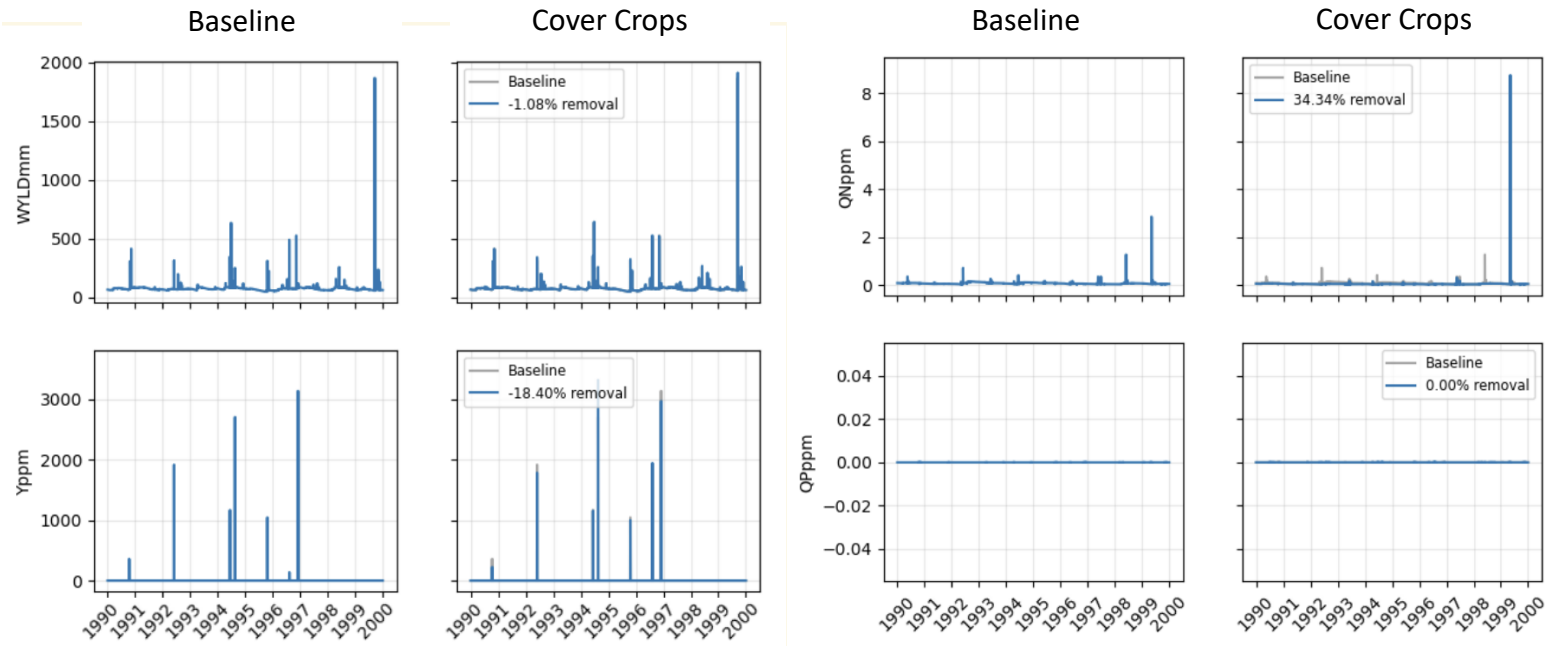
Ex: Appalachia baselines (no BMPs) → 1 baseline per region + LU combo

LU	APEX Runoff	CAST Runoff	APEX ET	CAST ET	APEX PET	CAST PET
Forest	50%	42-59	41%	41-59	60%	41-60
Hayland	45%	44-59	41%	41-57	58%	41-60
Pasture	46%	44-59	41%	41-57	60%	41-60
Row Crops	52%	45-60	41%	40-55	59%	41-60

Adjusting APEX parameters to ensure water balance matches CAST outputs

(reference values provided by Gopal Bhatt)

Example Output: Baseline v. Cover Crops



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Feedback: Operation Schedules

Ex: Appalachian row crops

Land use: straight row crop (good soil)

Operation Year	Month	Day	Operation	Equipment	Crop	Fertilizer ID	GDD	Fertilizer app. (kg/ha)	Plants/m^2
1	3	15	tillage	regular disk	corn				
1	5	1	plant corn	regular planter	corn		2000		10
1	5	1	fertilizer		corn	Nitrogen		24.67	
1	5	1	fertilizer		corn	Phosphorus		18.52	
1	5	16	fertilizer		corn	Nitrogen		94.7	
1	10	1	harvest	corn picker	corn				
1	10	1	kill corn	kill	corn				

* prepared document for other Appalachian baseline LUs

Progress Summary

- Baselines complete for all regions + land uses (16 scenarios)
- APEX source code debugging
- Validating baselines against CBP Phase 6 outputs

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Current Phase

- Continued validation
- BMP modeling
- Post-processing

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BMP Selection

CBP's Top 20 Most Implemented BMPs + CBP's Top 20 Most Effective BMPs + Feasibility Analysis

=

BMP	Land Use			
	Row Crops	Hay Land	Pasture	Forest
Grass Buffers	x	x	x	
Cover Crops*	x	x		
High Residue Tillage	x			
No Tillage*	x			
Manure Incorporation*	x	x		

*"easy wins" modeled

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Current Phase

- Continued validation
- BMP modeling
- Post-processing

Next Steps

- Removal efficiency analysis
- Future weather climate modeling (2055)

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